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Impact of the Cascade Hydropower Construction (HPC) on Water Quality of the Seyhan River, Turkey

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ABSTRACT

Cascade hydropower construction is a series of hydroelectric power stations located on different sections of river. Hydropower constructions (HPC) in the environment have both positive and negative effect. HPCs are works that have brought enormous benefits to providing electric energy, water storage, controlling floods, irrigation, transportation, human communities, and areas of recreation, etc. These engineering works can be providing large economic development in the regions where they are located. But, dam construction converts the natural stream flow to human control. This paper summarizes the impacts of cascade HPC on water quality in the Seyhan River. Water quality data were collected and data were divided into two stage: before HPC (1995-2008) and during HPC construction (2009-2014). Dam construction negatively affects water quality based on water quality data. The analysis results were compared with maximum permissible limit values recommended by Turkish Water Pollution Control Regulation (TWPCR) standards. The contents of all chemical and physical parameters are higher before construction, and water pollution was observed at HPC construction site. Also, biological oxygen demand, chloride, nitrite nitrogen, total dissolved solids and total coliform bacteria were found to be above TWPCR.

Keywords:
Cascade Hydropower; Environmental degradation; Seyhan River; Water pollution; Water quality

INTRODUCTION

Cascade HPC is an important engineering measure in dealing with the relationship between water and human being [1-4]. Water quality characteristics may change engineering constructions in a river system [5]. Dam construction may cause considerable impacts on river hydrology, water resource allocation [6]. Some studies have shown that dams can cause disturbances in downstream flow [7], sediment accumulation in reservoirs [8], and fluctuations in water levels [9]. Dam construction is an important issue for water resource management and is essential for environmental protection and policy making [10-11]. Cascade HPC is a major driver of land cover changes and has a confirmed influence on landscape pattern variation, independent of construction type [12-14]. Changes in the local microclimate and river-water quality have been described to result from this hydrological transformation [13]. Some researchers were studied on environmental deterioration of dam construction for different rivers in Turkey [16-19]. The Seyhan River Basin offers the people in the region various agricultural possibilities as dry farming, irrigated farming and livestock [20]. This basin has eight wildlife reserve sites, three wetlands and one nature conservation area. One of the wetlands (Lake Akyatan) has been declared as a Ramsar site (a wetland of international importance according to the Ramsar convention signed in 1971 by member countries) [21].

The present study summarizes the effect of cascade HPC on water quality in the Seyhan River basin during the 1995–2014 periods. Seyhan River basin has twenty two HPCs.

MATERIAL AND METHODS

Twelve HPCs were studied using site investigations from the Environmental Impact Assessment Reports (EIARs) for each dam. The EIARs contained information on geology, hydrogeology, water quality (physical, chemical and biological parameters), and dam characteristics. In order to assess the impact of cascade HPC on water quality, their process without interruption by dams must be known [22]. Water quality and quantity data were analyzed before construction (1995-2008) and during construction period (2009-2014). Data were obtained from the Feasibility Study Report for the HPC Stations and State Hydraulic Works Reports. Water quality data were evaluated in order to study the impact of HPCs on water quality of the Seyhan River.

Site Description

Seyhan River is the longest river in Turkey that flows into the Mediterranean Sea. The river is 560 km length and its source in Tahtalı Mountains (in Sivas and Kayseri provinces) to discharge in the Mediterranean. The river has

Figure 1. Location map of the Seyhan River

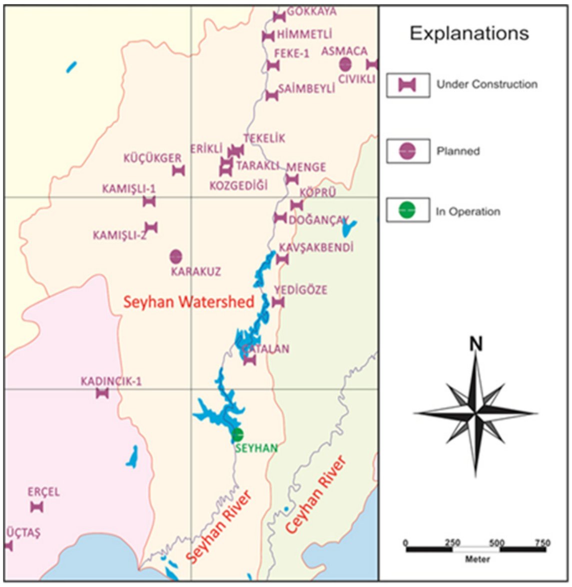

Figure 2. Location map of HPC on the Seyhan River hydrological watersheds

a 20731 km2 catchment area. The climate in the basin is strongly influenced by topography. The northern part of the basin exhibits the characteristics of central Anatolian climate. Annual precipitation is around 350-500 mm. The highest precipitation is observed at highlands, particularly around the Aladag region with an annual quantity of 1500 mm. The region between the coastal zone and Taurus Mountains has a semi-arid meso-thermal Mediterranean climate with dry and hot summers, and rainy and warm winters [20]. The annual precipitation is approximately 700 mm at the south of the basin [23]. The basin hosts the most fertile and productive agricultural lands of Turkey (Fig. 1).

Seyhan River basin is very attractive for agricultural and industrial perspectives. Additionaly, there are 18 cascade dams under construction (Data: State Hydraulic Works 2015) on the river for energy production and water supply (Fig. 2).

Water Quality

During the HPC phase, water mainly consumed in concrete production, washing of concrete aggregate, watering for dust suppression, and domestic purposes such as drinking, personnel usage. Water was used in concrete batching plant for washing of concrete aggregate and watering for dust suppression was supplied from the Seyhan River and its tributaries. Seyhan Dam Lake and Catalan Dam Lake now compensate for the lack of major water bodies in the region. In terms of hydrological features, Göksu, Zamantı and Pozantı streams are the main streams and they merge to form Seyhan River in the northern basin. Totally 18 cascade HPCs are under construction with the total installed capacity of 7869.9 Megawatt (MW) and the annual generating capacity of 3261.175 Gigawatthour (GWh) (Table 1).

Surface water samples for analysis were taken from the 12 different locations of Seyhan River before HPCs stage by EIE (General Directorate of Electrical Power Resources Survey and Development Administration). The coordinates of surface water sampling locations are given in Table 2. At the 12 water quality monitoring stations (Table 2), operated by EIE, collected samples were analyzed for temperature (°C) and pH value at site while collecting water sample. . The collected water sample bottles were sealed at site and transported to the chemical lab for the detail analysis. The ion contents were measured by using titration techniques, flame photometer, spectrophotometer etc. The parameters such as pH, electrical conductivity (EC), Dissolved Oxygen (O_2), chloride (Cl^-), Sulfate (SO_4), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Nitrate Nitrogen (NO_3-N), Nitrite Nitrogen (NO_2-N), Iron (Fe), Manga-

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Table 1. Description of cascade dams [24-33] .

Dam Project Name	Province	Total Install Capacity (MW)	Total Energy (GWh/year)	Present stage
Asmaca	Adana	22	72	Master Planned
Cıvıklı	Adana	0.32	1.39	Under Const.
Catalan	Adana	169	596	In operation
Erikli	Adana	0.96	3.5	Under Const.
Kamışlı-1	Adana	4.3	20.34	Under Const.
Kamışlı-2	Adana	15.54	79.01	Under Const.
Karakuz	Adana	96	444	Master Planned
Kozgediği	Adana	2.03	6.98	Under Const.
Küçükger	Adana	0.89	6.98	Under Const.
Seyhan	Adana	54	350	In operation
Taraklı	Adana	0.56	1.87	Under Const.
Tekelik	Adana	0.56	1.74	Under Const.
Yamanli I	Adana	22	100	Under Const.
Yamanlı II	Adana	78	308	Under Const.
Yamanli III	Adana	30	119.116	Under Const.
Saimbeyli	Adana	8.76	237.940	Under Const.
Himmetli	Adana	27	106.159	Under Const.
Feke I	Adana	30	117	Under Const.
Feke II	Adana	70	225	Under Const.
Dogancay	Adana	49.17	190.15	Under Const.
Kavsakbendi	Adana	181.81	715	Under Const.
Yedigoze	Adana	300	949	Under Const.

nese (Mn), Alluminium (Al), TDS (Total Dissolved Solids) were analyzed for collected water samples. Statistics of the 13 mean parameters for 13 years before the construction stage (1995-2008) used in present study is given in Table 3.

Table 2. The coordinates of surface water sampling locations during the construction stage [24-33] .

Sample Location	Coordinates		
	UTM Zone	East	North
Cukurkısla Dam	37 S	262762	4225971
Saimbeyli Dam	37 S	243059	4199331
Gokkaya Dam	37 S	244614	4194416
Yamanli III Dam	37 S	239228	4194879
Feke I Dam	36 S	762380	4195577
Asmaca Dam	36 S	754994	4190292
Feke II Dam	36 S	751394	4181653
Kopru Dam	36 S	736731	4166333
Kavsakbendi Dam	36 S	723536	4160876
Menge Dam	36 S	739670	4176823
Yedigoze Dam	36 S	717046	4141802
Dogancay Dam	36 S	714330	4161283

Table 3. Mean values of water quality characteristics before the construction stage (1995-2008) [46-48] .

Parameter	Unit	Mean values of 13 year
Temperature	C	12.5
pH	SU	6-9
Dissolved Oxygen (O_2)	mgL^{-1}	3-5
Chloride (Cl)	mgL^{-1}	na
Sulfate (SO_4)	mgL^{-1}	13.5
Chemical Oxygen Demand (COD)	mgL^{-1}	>70
Biological Oxygen Demand (BOD)	mgL^{-1}	0.6
Nitrate Nitrogen (NO_3-N)	mgL^{-1}	0.8
Nitrite Nitrogen (NO_2-N)	mgL^{-1}	>0.005
Iron (Fe)	mgL^{-1}	>0.5
Manganese (Mn)	mgL^{-1}	>3
Alluminium (Al)	mgL^{-1}	>1
TDS (Total Dissolved Solids)	mgL^{-1}	300

RESULTS AND DISCUSSION

Water quality in many large river waters has deteriorated significantly worldwide due to anthropogenic activities in the past two-three decades [34]. Pollution entering the rivers from agricultural runoff has caused significant increases in nutrient concentrations such as nitrogen (N) and phosphorus (P) [35-37]. It is also widely accepted that wastewaters from treatment plants supply significant amounts of P to rivers, particularly in populated urban areas [38]. Nutrient enrichment can result in excessive growth of aquatic plants, algae productivity and reductions in dissolved oxygen in rivers [39]. Turkey is still engaged in its "hydraulic mission" characterized by intensive dam and irrigation canal constructions [40] because water resource management is still at an early stage. The EU Water Framework Directive (WFD) is also likely to bring monetary support for improving the country's water infrastructure and pollution prevention measures [41-42]. These characteristics make Turkey a country where, similarly to other rapidly developing economies [40] such as Brazil [43] and China [44], the nutrient cycle is increasingly controlled by human activities as opposed to natural processes [44]. The waters in the Seyhan River system provide many ecosystem functions including public drinking water supply, industrial water supply, irrigation water for agriculture, cultural and sporting activities such as swimming and fishing and conservation value for wildlife habitats, fisheries and biodiversity [40].

The aim of this study was to examine to determine water quality of Seyhan River before and during HPC. According to TWPCR [45] Official Gazette, water quality of inland waters is classified into four groups as: high quality waters (Class I), moderate quality waters (Class II), polluted waters (Class III), and highly polluted waters (Class IV). There are 18 dams on the Seyhan River that are under construction for energy production and water supply. All the water quality data were collected and data were divided into two stage: before HPC period (1995-2008) and HPC period (2009-2014). The comparison of water quality characteristics of the HPCs during two stages, i.e, before and during HPC, enabled us to assess changes in the Seyhan River. Impact of HPC on Seyhan River water quality was analyzed, which were helpful for understanding the environmental features of the entire watershed. Based on the water quality data, HPCs are negatively affected water quality. According to Fig. 3, dissolved oxygen value is limited and total dissolved solids value is very high at the costruction period (2009-2014).

The catchment has been monitored for flow and water quality at over 12 monitoring stations for 47 determinands. To determine sampling locations pervious locations of Feasibility Study studies, locations determined during monitoring period were considered to facilitate comparati-

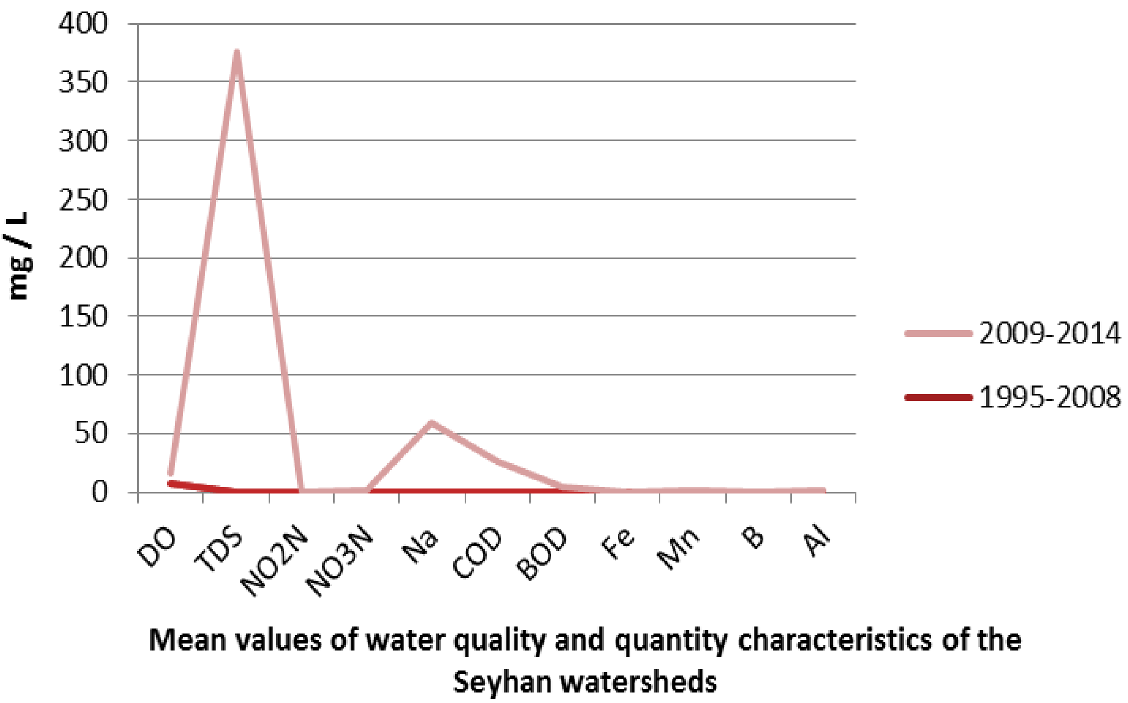

Figure 3. Location map of HPC on the Seyhan River hydrological watersheds

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Table 4. Mean values of water quality characteristics during the construction (2009-2014) stage [24-33, 49].

		Surface water quality measurement locations											
Parameter	*Unit*	*Cukurkisla Dam*	*Saimbeyli Dam*	*Gokkaya Dam*	*Yamanli III Dam*	*Feke I Dam*	*Asmaca Dam*	*Feke II Dam*	*Kopru Dam*	*Kavsakbendi Dam*	*Menge Dam*	*Yedigoze Dam*	*Dogancay Dam*
Temperature	C	9.3	12.8	11.8	12.1	12.0	11.9	12.1	13.9	14.1	13.3	14.9	12.7
pH	SU	7.94	8.25	7.92	7.88	7.89	8.22	7.91	8.08	8.08	8.13	7.84	8.85
Dissolved Oxygen (O_2)	mgL^{-1}	9.38	10.55	9.99	9.88	9.91	10.22	9.37	9.26	9.60	8.94	8.27	9.72
Oxygen Saturation (% O_2)	%	114.7	126.6	120.7	119.7	120.7	124.0	114.1	112.6	117.2	109.6	101.7	120.8
Chloride (Cl)	mgL^{-1}	6.5	5.0	8.5	7.5	8.0	46.0	584.8	119.5	69.5	125.0	65.0	8.0
Sulfate (SO_4)	mgL^{-1}	13.5	18.6	93.5	92.4	88.1	56.3	117.1	79.7	54.3	84.5	45.3	4.9
TSS (Total Suspended Solids)*	mgL^{-1}	9.2	< 1.0 **	108.4	359	144.1	< 1.0 **	< 1.0 **	24.8	100.4	6.8	2.4	< 1.0 **
Ammonium Nitrogen (NH_4-N)	mgL^{-1}	< 0.15 **	0.18	< 0.15 **	< 0.15 **	< 0.15 **	0.17	0.36	0.59	< 0.15 **	< 0.15 **	< 0.15 **	0.19
Nitrate Nitrogen (NO_3-N)	mgL^{-1}	1.40	1.10	0.96	0.94	0.99	0.55	0.92	0.78	0.92	0.77	0.98	0.23
Nitrite Nitrogen (NO_2-N)	mgL^{-1}	0.012	0.025	0.004	0.006	0.008	< 0.002	0.009	0.005	0.005	0.005	< 0.002	0.004
Total Phosphorus (P)	mgL^{-1}	< 0.3 **	< 0.3 **	0.5	3.5	1.7	< 0.3 **	< 0.3 **	< 0.3 **	< 0.3 **	< 0.3 **	< 0.3 **	< 0.3 **
TDS (Total Dissolved Solids)	mgL^{-1}	10.0	260.0	326.0	304.0	238.0	382.0	1,324.0	326.0	292.0	370.0	366.0	302.0
Color	mgL^{-1} Pt/Co scale	7.1	7.6	7.1	7.6	8.2	7.1	6.0	4.9	6.5	4.3	6.5	6.0
Sodium (Na)	mgL^{-1}	4.555	4.390	6.303	6.067	6.280	30.350	375.20	108.30	43.41	73.46	43.97	6.60
Chemical Oxygen Demand (COD)	mgL^{-1}	< 20.0 **	< 20.0 **	20.3	31.9	64.2	< 20.0 **	34.9	< 20.0 **	< 20.0 **	< 20.0 **	< 20.0 **	< 20.0 **
Biological Oxygen Demand (BOD)	mgL^{-1}	< 4.0 **	< 4.0 **	5.0	7.8	5.8	< 4.0 **	< 4.0 **	< 4.0 **	< 4.0 **	< 4.0 **	< 4.0 **	< 4.0 **
TOC (Total Organic Carbon)	mgL^{-1}	1.1	1.0	0.9	1.6	0.9	1.0	1.0	0.7	0.9	0.9	1.2	1.0
Total Kjeldahl Nitrogen (TKN)	mgL^{-1}	1.7	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
Oil and grease**	mgL^{-1}	< 1.5 **	3.6	< 1.5 **	1.6	< 1.5 **	< 1.5 **	< 1.5 **	< 1.5 **	< 1.5 **	1.6	< 1.5 **	< 1.5 **
MBAS ((materials giving rxn with methly blue.)	mgL^{-1}	0.06	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **	< 0.06 **
Phenols	mgL^{-1}	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Table 4. Mean values of water quality characteristics during the construction (2009-2014) stage [24-33, 49](continued).

Parameter	Unit	Surface water quality measurement locations											
		Cukurkisla Dam	Saimbeyli Dam	Gokkaya Dam	Yamanli III Dam	Feke I Dam	Asmaca Dam	Feke II Dam	Kopru Dam	Kavsakbendi Dam	Menge Dam	Yedigoze Dam	Dogancay Dam
Mineral Oils (C10- C40-Index)	mgL^{-1}	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	<0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)	< 0.1(LOD)
Pesticides (30 parameters)***	SU	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}	<0.05x 10^{-3}
Mercury (Hg)	mgL^{-1}	<0.0030	< 0.0030	< 0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	< 0.0030	<0.0030	< 0.0030	< 0.0030
Cadmium (Cd)	mgL^{-1}	0.0053	0.0056	0.0057	0.0053	0.0055	0.0054	0.0053	0.0055	0.0056	0.0056	0.0054	0.0055
Lead (Pb)	mgL^{-1}	<0.0100	< 0.0100	< 0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	< 0.0100	<0.0100	< 0.0100	< 0.0100
Arsenic (As)	mgL^{-1}	<0.0030	< 0.0030	0.0106	0.0098	0.0117	<0.0030	0.0089	0.0056	< 0.0030	0.0076	< 0.0030	< 0.0030
Copper (Cu)	mgL^{-1}	0.0705	0.0707	0.0792	0.0772	0.0980	0.0785	0.0698	0.0840	0.0698	0.0550	0.0618	0.0696
Chromium (Cr), Total	mgL^{-1}	<0.010	< 0.010	< 0.010	<0.010	<0.010	<0.010	<0.010	<0.010	< 0.010	<0.010	< 0.010	< 0.010
Chromium (Cr6+)	mgL^{-1}	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cobalt (Co)	mgL^{-1}	<0.0030	< 0.0030	< 0.0030	0.0032	<0.0030	<0.0030	<0.0030	<0.0030	0.0063	<0.0030	< 0.0030	< 0.0030
Nickel (Ni)	mgL^{-1}	<0.0100	< 0.0100	< 0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	0.0597	<0.0100	< 0.0100	< 0.0100
Zinc (Zn)	mgL^{-1}	0.0324	0.0451	0.0500	0.0482	0.0671	0.0386	0.0293	0.0388	0.0353	0.0352	0.0341	0.0347
Total cyanide (CN-)	mgL^{-1}	<0.002	< 0.002	< 0.002	< 0.002	<0.002	< 0.002	<0.002	<0.002	< 0.002	<0.002	< 0.002	< 0.002
Florure (F-)	mgL^{-1}	< 0.3	< 0.3	0.3	< 0.3	0.3	< 0.3	0.5	0.4	0.3	0.4	0.3	0.3
Free Chlorine (Cl_2)	mgL^{-1}	0.09	0.05	0.10	0.12	0.14	0.02	0.05	0.13	0.03	0.07	0.03	0.03
Sulphur (S_2-)	mgL^{-1}	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Iron (Fe)	mgL^{-1}	0.1844	0.1875	0.8178	2.8850	1.7290	0.1280	0.1509	0.2581	1.4930	0.1773	0.1717	0.0859
Manganese (Mn)	mgL^{-1}	0.0255	0.5004	0.0614	0.1686	0.0617	0.0632	0.0333	0.2327	0.0725	0.0385	0.2044	0.0125
Boron (B)	mgL^{-1}	0.2136	0.3098	0.3700	0.2373	0.1211	<0.010	0.7306	< 0.0100	< 0.0100	< 0.0100	< 0.0100	< 0.0100
Selenium (Se)	mgL^{-1}	0.0070	0.0070	0.0116	<0.0050	0.0071	<0.005	<0.005	0.0054	0.0080	0.0076	0.0093	0.0098
Barium (Ba)	mgL^{-1}	0.0554	0.0524	0.0610	0.0792	0.0618	0.0883	0.0570	0.0717	0.0743	0.0671	0.0768	0.0196
Aluminium (Al)	mgL^{-1}	0.0812	0.0354	0.3092	0.6985	0.3726	0.0256	0.0490	0.1261	0.2000	0.0822	0.0699	0.0274
Fecal Coliform Bacteria	kob/100 mL	265	250	> 1000	> 1000	> 1000	160	210	>1000	> 1000	70	100	88
Total Coliform Bacteria	kob/100 mL	840	820	> 1000	> 1000	> 1000	610	720	>1000	> 1000	320	480	560

Table 4. Mean values of water quality characteristics during the construction (2009-2014) stage [24-33, 49](continued).

Parameter	*Unit*	*Surface water quality measurement locations*											
		Cukurkisla Dam	*Saimbeyli Dam*	*Gokkaya Dam*	*Yamanli III Dam*	*Feke I Dam*	*Asmaca Dam*	*Feke II Dam*	*Kopru Dam*	*Kavsakbendi Dam*	*Menge Dam*	*Yedigoze Dam*	*Dogancay Dam*
Radioactivity (Alfaactivity)	*Bq/L*	*< 0.07*	*< 0.08*	*< 0.09*	*< 0.26*	*< 0.12*	*< 0.09*	*< 0.19*	*< 0.08*	*< 0.09*	*< 0.08*	*< 0.08*	*< 0.04*
Beta Activity	*Bq/L*	*0.08*	*0.09*	*0.10*	*0.24*	*0.14*	*0.07*	*0.71*	*0.15*	*0.12*	*0.17*	*0.09*	*0.06*

LOD Limit of Detection
** TSS parameter cannot be compared with Table 4 in TWPCR because there is no classification in Table 5.*
*** It is observed that the detection limit for these analysis by using those methods are not possible to conduct other more precise measurement*
**** 31 Pesticides parameters are analyzed by Agrolab Labor gruppe. In Table 5 of TWPCR, the limit value for pesticides is given as "Total Pesticides" but detailed list or explanation of these pesticides is not given. Therefore, it is determined that all 31 Pesticides are below "Class I" limit value since they are under "0.05 x 10⁻³" mgL⁻¹.*

ve analysis. Since 2014, samples at 12 HPC sites have been collected regularly in January, April, July and October. Thus in this study, I used data from 2009 to 2014 at these HPCs sites. Water quality parameters like temperature, pH, total dissolved solids, and electric conductivity were measured in the sites using, a thermometer, pH meter, conductivity meter and TDS meter respectively. For dissolved oxygen (DO), samples were collected into 300-ml plain glass bottles and the DO fixed using the azide modification of the Winkler's method. Samples for bacteriological analyses were collected into sterilized plain glass bottles. For oil, grease, and other parameters samples were collected in simple plastic bottles. All samples of 12 stations were stored in an icebox and transported to Encon Environmental Laboratory for analyses. The method used for water quality tests are presented below in the Table 4. Water quality determinands presented in this paper are dissolved oxygen (DO), biological oxygen demand (BOD), ammonium (NH_4-N), nitrite (NO_2 -N), nitrate (NO_3-N) as well as major dissolved ions. Water quality classes were determined based on the water quality criteria presented in Table 5.

The variations in water quality parameters from 1995 to 2014 were evaluated and standardized. Some of the the major parameters (e.g. NO_2-N, NO_3-N, TDS, COD, BOD, Fe, Mn, B, Al) were evaluated corresponding to before construction (1995-2008) and during construction (2009-2014) periods. According to the Table 5, the water quality is listed from good quality to worse, respectively class I, II, III and IV. Since any water resource should satisfy all the parameters given for a category to be classified as within that water quality class. It can be stated that the quality class of surface water in Dogancay Dam and Yedigoze Dam are Class II water quality. Cukur Kısla, Gokkaya Dam, Kopru Dam, Kavsakbendi Dam are Class III and Saimbeyli Dam, Yamanli III Dam, Feke I Dam, Feke II Dam, and Menge Dam is Class IV water quality. Water quality is decreased depending on constrution facilities (Fig. 3).

The obtained results have been compared with those from literature [50-53], and it can be observed a similarity with these, where the authors show high incidence of pathogenic and opportunistic bacteria isolated different water resources. The existing literature and observational data demonstrate that the cascading dams have led to a decline in the flood season water discharge and annual sediment flux within Turkey borders, reservoir aggradations, and degradation of water quality within the reservoirs. Furthermore, the dams have negatively affected the riverine aquatic biological communities and fish assemblages [54-55]. During the construction stage, due to the lack of dissolved oxygen, fish assemblages tried to get oxygen from the air in the Seyhan Dam reservoir (Fig.4a, b).

Table 5. Turkish Water Pollution Control Regulation [45].

Parameter	Water quality classes I	II	III	IV
General conditions				
Temperature (ºC)	≤ 25	≤ 30	≤ 30	> 30
Color	RES 436 nm: ≤ 1,5 RES 525 nm: ≤ 1,2 RES 620 nm: ≤ 0,8	RES 436 nm: 3 RES 525 nm: 2,4 RES 620 nm: 1,7	RES 436 nm: 4,3 RES 525 nm: 3,7 RES 620 nm: 2,5	RES 436 nm: >4,3 RES 525 nm: >3,7 RES 620 nm: >2,5
pH	6,5-8,5	6,5-8,5	6,0-9,0	< 6,0 veya > 9,0
Electrical conductivity (µS/cm)	< 400	1000	3000	> 3000
Oil and grease (mgL-1)	Floating liquids such as oil, tar, garbage and similar solid materials and foam can not be found.			-
(A) Oxygenation Parameters				
Oxygen Saturation (%) (b)	>90	70	40	< 40
Dissolved Oxygen (mgL^{-1})	> 8	6	3	< 3
Chemical Oxygen Demand (COD)) mgL^{-1}	< 25	50	70	> 70
Biological Oxygen Demand (BOD)) mgL^{-1}	< 4	8	20	> 20
B) Nutrient (Nutrient Elements) Parameters				
Ammonium Nitrogen (NH_4-N) mgL^{-1}	< 0,2	1	2	> 2
Nitrate Nitrogen (NO_3-N) mgL^{-1}	< 5	10	20	> 20
Nitrite Nitrogen (NO_2-N) mgL^{-1}	< 0,01	0,06	0,12	> 0,3
Total Kjeldahl Nitrogen (TKN)	< 0,5	1,5	5	> 5
Total phosphorus (mg P/L)	< 0,03	0,16	0,65	> 0,65
C) Trace Elements (Metals) and Inorganic Pollution Parameters				
Aluminium (Al) (mgL^{-1})	≤ 0,3	≤ 0,3	1	> 1
Arsenic (µg/L)	≤ 20	50	100	> 100
Copper (µg/L)	≤ 20	50	200	> 200
Barium (µg/L)	≤ 1000	2000	2000	> 2000
Boron (µg/L)	≤ 1000	≤ 1000	≤ 1000	> 1000
Mercury (µg/L)	≤ 0,1	0,5	2	> 2
Zinc (µg/L)	≤ 200	500	2000	> 2000
Iron (µg/L)	≤ 300	1000	5000	> 5000
Florür (µg/L)	≤ 1000	1500	2000	> 2000
Cadmium (µg/L)	≤ 2	5	7	> 7
Cobalt (µg/L)	≤ 10	20	200	> 200
Chromium (µg Cr+6/L)	Not measurable	20	50	> 50
Chromium (total) (µg/L)	≤ 20	50	200	> 200
Lead (µg/L)	≤ 10	20	50	> 50
Manganese (µg Mn/L)	≤ 100	500	3000	> 3000
Nickel (µg/L)	≤ 20	50	200	> 200

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Table 5. Turkish Water Pollution Control Regulation [45] *(continued)*.

Parameter	*Water quality classes* I	II	III	IV
C) Trace Elements (Metals) and Inorganic Pollution Parameters(continued)				
Selenium (μg Se/L)	≤ 10	≤ 10	20	> 20
Serbest klor (μg Cl_2/L)	≤ 10	≤ 10	50	> 50
Cyanide (total) (μg/L)	≤ 10	50	100	> 100
Sulphur (μg/L)	≤ 2	≤ 2	10	> 10
Dangerous materials	*Dangerous substances and other pollutants not provided in this tablature will be evaluated from 1 January 2016 after the relevant country inventory (reference values) has been created.*			
D) Bacteriological Parameters				
Fecal Coliform Bacteria (numbers/100 mL)	≤10	200	2000	> 2000
Total Coliform Bacteria (numbers/100 mL)	≤100	20000	100000	> 100000

I. High quality waters
II. Moderately quality waters
III. Polluted waters
IV. Extremely polluted water

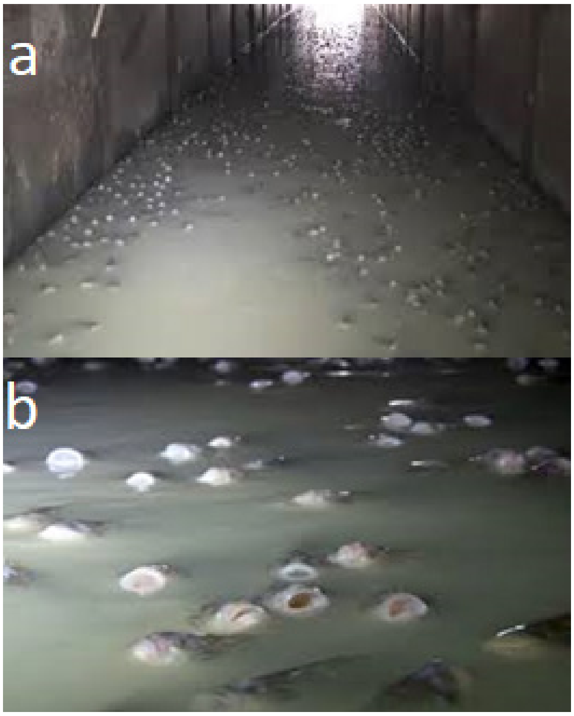

Figure 4. The struggle for survival of fish assemblages

These photos are the best way to show the environmental impact of dams. Photos were taken on February 5, 2015.

CONCLUSION

As a one of active international research areas, studies on the impact of HPCs on water quality and environment deterioration is a new task in the basin management in Turkey. This study evaluated the impact of HPCs on water quality in the Seyhan River. According to analyzing results, covering the period 1995-2008 was evaluated taking into consideration the major parameters. The quality of the water meets the requirements of Class I water specified in the TWPCR regulations. Evaluation of construction period (2009-2014), BOD, Cl, NO2-N, TDS and Total Coliform Bacteria values were increased. This increase points out the pollution related to the construction activities. Water quality characteristics were evaluated results of the "Feasibility Study Report for the HPC Stations" and "the General Plan of the EIE", from the different stations of the Seyhan River. The results show that the water can be used for municipal and aggricultural purposes.

However, this paper is evaluated the impact of cascade dams on water quality at the before and during construction stage. Further analysis regarding environmental protection is needed. Issues such as intensive human activities on land use cannot be addressed here. In order to achieve a unified operation of HPCs for water quality, especially during water pollution events, an optimal monitoring program needs to be developed as well.

Consequently, these cascade HPCs have led to changes in the quality of the water. Careful planning and a design process that incorporate the public involvement are crucial to minimize the negative effects of the cascade HPC on the environment. When the appropriate mitigation measure are identified early in the planning and design process for cascade HPCs, they can be effectively and efficiently incorporated into the design, construction and operation of the project. Therefore, a long-term basin-wide terrestrial and

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aquatic environment and ecosystem monitoring program consisting of permanent field monitoring stations and multiscale Environmental Sensor Networks should be planned and implemented to obtain additional geological, hydrological, ecological, meteorlogical and biodiversity information. The main recommendations are for planners, developers, financial institutions and environmental managers to reduce damage to a minimum through rational and intelligent solutions. They have negatively affected environmental deterioration and water quality.

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References

1. Hu WW, Wang GX, Deng W, Li SN. The influence of dams on ecohydrological conditions in the Huaihe River basin, China. Ecological Eng. 33(3-4) (2008) 233-241.
2. Burke M, Jorde K, Buffington JM. Application of a hierarchical framework for assessing environmental impacts of dam operation: Changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. J Environ Manage. 90 (2009) 224-236.
3. Zhao Q, Liu S, Deng L, Dong S, Yang J, Wang C. The effects of dam construction and precipitation variability on hydrologic alteration in the Lancang River basin of southwest China. Stoch Environ Res Risk Assess. 26 (2012) 993-1011.
4. Morimoto R. Incorporating socio-environmental considerations into project assessment models using multi-criteria analysis: A case study of Sri Lankan hydropower projects. Energy Policy 59 (2013) 643-653.
5. Huang WR, Foo S Neural network modeling of salinity variation in Apalachicola River. Water Res. 36 (2002) 356-362.fdf
6. Tealdi S, Camporeale C, Ridolfi L. Modeling the impact of river damming on riparian vegetation. J Hydrology 396(3-4) (2011) 302-312.
7. Elhatip H, Hinis MA, Gulbahar N. Evaluation of the water quality at Tahtali Dam watershed in Izmir -Turkey by means of statistical methodology. Stoch Environ Res Risk Assess. 22(3) (2008) 391–400.
8. Snyder NP, Rubin DM, Alpers CN, Childs JR, Curtis JA, Flint LE, Wright SA. Estimating accumulation rates and physical properties of sediment behind a dam: Englebright Lake, Yuba River, northern California. Water Res Research 40(11) (2004) W11301.
9. Lee JY, Choı YK, Kim HS, Yun ST. Hydrologic characteristics of a large rockfill dam: implications for water leakage. Eng Geol. 80 (1-2) (2005) 43-59.
10. Bunkei M, Ming X, Takehiko F. Characterizing the changes in landscape structure in the Lake Kasumigaura Basin, Japan using a high-quality GIS dataset. Landscape Urban Plan. 78 (2006) 241-250.
11. Chon, H., Vassilev, A., DePamphilis, M.L., Zhao, Y., Zhang, J., Burgers, P.M., Crouch, R.J., and Cerritelli, S.M. Contributions of the two accessory subunits, RNASEH2B and RNASEH2C, to the activity and properties of the human RNase H2 complex. Nucleic Acids Res. 37 (2009) 96-110.
12. Hooke, J.M., Human impacts on fluvial systems in the Mediterranean region. Geomorphology 79(3–4) (2006) 311–335.
13. Ouyang W, Skidmore AK, Hao FH, Toxopeus AG, Abkar A. Accumulated effects on landscape pattern by hydroelectric cascade exploitation in the Yellow River basin 1976 to 2006. Landscape Urban Plan. 93(3-4) (2009) 163-171.
14. Liu S, Zhao Q, Wen M, Deng L, Dong S, Wang C. Assessing the impact of hydroelectric project construction on the ecological integrity of the Nuozhadu Nature Reserve, southwest China. Stoch Environ Res Risk Assess. 27 (2013) 1709-1718.
15. Ouyang W, Hao F, Song K, Zhang X. Cascade dam-induced hydrological disturbance and environmental impact in the upper stream of the Yellow River. Water Res Manag. 25 (2011) 913-927.
16. Akkoyunlu A. Water quality assessment of Omerli Dam reservoir (Istanbul, Turkey). Freseneus Environ Bull 11 (2002) 208-217.
17. Kurunc A, Yureklı K, Okman C. Effects of Kilickaya Dam on concentration and load values of water quality constituents in Kelkit Stream in Turkey. J Hydrology 317 (2006) 17-30.
18. Tahmicioglu MS, Anul N, Ekmekci F, Durmus N. Positive and negative impact of dams on the environment, International Congress on River Basin Management, Turkey, Chapter 2, 759-769, 2007.
19. Tanrıverdı C, Alp A, Demırkıran AR, Uçkardes F. Assessment of surface water quality of the Ceyhan River basin, Turkey. Environ Monit Assess. 167 (2010) 175-184.
20. Golge M, Yenilmez F, Aksoy A. Development of pollution indices for the middle section of the Lower Seyhan Basin (Turkey). Ecological Indicator 29 (2013) 6-17.
21. RAMSAR (2012) The Ramsar Sites Database.Database/Searchforsites/tabid/765/Default.aspx. http://ramsar.wetlands.org/ (Accessed 1 Nov 2016).
22. Zhang Y, Xia J, Liang T, Shao Q. Impact of water projects on river flow regimes and water quality in Huai River basin. Water Res Manag. 24 (2009) 889-908.
23. Fujihara Y, Tanaka K, Watanabe T, Nagano T, Kojiri T. Assessing the impacts of climate change on the water resources of the Seyhan River Basin in Turkey: Use of dynamically downscaled data for hydrologic simulations. J Hydrology 353 (2008) 33-48.
24. Dokay Environmental Engineering Co. Yedigoze Dam, HEPP and Quarries Project Final EIA Report, Ankara, 2007.
25. Cınar Engineering Co. Yamanli III HEPP EIA Report, Ankara, 2008.
26. Prd Construction Co. Feke II Dam and HEPP, EIA Report, Ankara, 2008.
27. Cınar Engineering Co. Feke I Weir and HEPP Project Information Report, Ankara, 2009.
28. Dokay Environmental Engineering Co. Kavsakbendi Dam and HEPP Capacity Increase Final EIA Report, Ankara, 2009a.
29. Dokay Environmental Engineering Co. Yamanli II Weir, HEPP and Quarries Final EIA Report, Ankara, 2009b.
30. Dokay Environmental Engineering Co. Kopru Dam and HEPP Final EIA Report, Ankara, 2009c.
31. Dokay Environmental Engineering Co. Menge Dam and HEPP Final EIA Report, Ankara, 2009d.
32. Selin Const. Co. Dogancay Weir and HEPP, Final EIA Report, Ankara, 2009.

33. Selin Const. Co. Saimbeyli Weir and HEPP, EIA Introduction Report, Ankara, 2010.
34. Ferrier RC, Edwards AC, Hirst D, Littlewood IG, Watts CD, Morris R. Water Quality of Scottish Rivers: Spatial and Temporal Trends. Sci Total Environ. 265(1-3) (2001) 327-342.
35. Neal C, Jarvie HP, Love A, Neal M, Wickham H, Harman S. Water quality along a river continuum subject to point and diffuse sources. J Hydrology 350(3-4) (2008) 154-165.
36. Royer TV, David MB, Gentry LE. Timing of riverine export of nitrate and phosphorus from agricultural watersheds in ILLINOIS: Implications for reducing nutrient loading to the Mississippi River. Environ Sci Tech. 40(13) (2006) 4126-4131.
37. Withers PJA, Lord EI. Agricultural nutrient inputs to rivers and groundwaters in the UK: Policy, Environmental management and research needs. Sci Total Environ. 282(1) (2002) 9-24.
38. Jarvie HP, Neal C, Withers PJA. Sewage-Effluent phosphorus: A greater risk to river eutrophication than agricultural phosphorus? Sci Total Environ. 360(1-3) (2006) 246-253.
39. Whitehead PG, Johnes PJ, Butterfield D. Steady state and dynamic modelling of nitrogen in the River Kennet: Impacts of land use change since the 1930s, Sci Total Environ. 282(2002) 417-434.
40. Jin L, Whitehead P, Hadjikakou M. A study of the Yesilirmak River catchment in Northern Turkey: Spatial patterns and temporal trends in water quality. J Environ Protec 4(2013) 104-120.
41. Kibaroglu A. Analysis of the integrated water resources management approach: Turkey-EU water relations as a case study, Paper presented in BALWOIS 2008 (Balkan Water Observation and Information Systems for Balkan Countries), Ohrid, 27-31 May 2008.
42. Gurluk S. Turkey's challenges of river basin management and ımplementation of the European Union Water Framework Directive, Paper presented in BALWOIS 2008 (Balkan Water Observation and Information Systems for Balkan countries). Ohrid, 27-31 May 2008.
43. Filoso S, Martinelli LA, Howarth RW, Boyer EW, Dentener F. Human activities changing the nitrogen cycle in Brazil. Biogeochem 79(1-2) (2006) 61-89.
44. Xia J, Cheng S, Hao X, Xia R, Liu X. Potential impacts and challenges of climate change on water quality and ecosystem: case studies in representative rivers in China. J Resour Ecology 1(1) (2010) 31-35.
45. Turkish Water Pollution Control Regulation, Official Gazette No. 25687 dated December 31, 2004 and revised in Official Gazette No. 28257 dated October 30, 2012.
46. General Directorate of Electrical Power Resources Survey and Development Administration (EIE) Water Discharges, Ankara, 305 pp. 2010.
47. Devlet Su Isleri Genel Müdürlügü, Seyhan Havzası Master Plan Raporu, DSI 6 Bölge Müdürlügü, Adana, 2014.
48. Devlet Su Işleri Genel Müdürlügü, Adana DSI 6 Bölge Müdürlüğü ve Kayseri DSI 12 Bölge Müdürlügü Takdim Raporları, 2015.
49. TÜBİTAK (The Scientific & Technical Research Council of Turkey) MAM ÇEVRE ENSTİTÜSÜ, Havza koruma eylem planları - Seyhan Havzası. 459 pp. http://www.cygm.gov.tr/CYGM/Files/Guncelbelgeler/HAVZA_FiNAL/Seyhan/Seyhan_Havzasi.pdf
50. Kinge CW, Mbewe M. Bacterial contamination levels in river catchments of the North West Province, South Africa: Public health implications. Afr J Microbiol Res. 6(7) (2012) 1370 - 1375.
51. Niewolak S, Opieka A. Potentially pathogenic microorganisms in water and bottom sediments in the Czarna Hańcza River. Pol J Environ Stud. 9 (2000) 183-194.
52. Orozco LN, Felix EA, Ciapara IH, Flores RJ, Cano R. Pathogenic and non-pathogenic Vibrio species in aquaculture shrimp ponds. Rev Microbiol. 49(3-4) (2007) 60-67.
53. Obi CL, Bessong PO, Momba MNB, Potgieter N, Samie A, Igumbor IE. Profiles of antibiotic susceptibilities of bacterial isolates and physico-chemical quality of water supply in rural venda communities, South Africa. Water SA 30(4) (2004) 515-520.
54. Bai J, Xiao R, Cui B, Zhang K, Wang Q, Liu X, Gao H, Huang L. Assessment of heavy metal pollution in wetland soils from the young and old reclaimed regions in the Pearl River Estuary, South China. Environ Poll. 159 (2011) 824-917.
55. Wang QG, Du YH, Su Y, Chen KQ. Environmental impact post-assessment of dam and reservoir projects: A review. Procedia Environ Sci. 13 (2012) 1439-1443.